

Water Supply

The main urban centers from Boston to Baltimore consume 2,000,000 gallons of water daily. The investment of New York in dams and reservoirs are \$66,000,000. The adjacent communities in New Jersey plan a development to cost about \$45,000,000. Baltimore is at work on a \$30,000,000 project. San Francisco and the immediate vicinity will shortly obtain part of their public water supplies from the Hetch Hetchy Reservoir 200 miles away, built at a cost of \$126,500,000. The water system by which Southern California plans to solve its water problems primarily in domestic supplies will cost \$350,000,000.

Irrigated Land

Table gives acreage of irrigated area 19,547,544 acres. Value of lands, buildings, and machinery \$4,886,892,784. Value of reservoirs and distributing systems \$1,032,755,790.

Definition
of
forest
cover
A 2

Forest Forest cover in its relation to watershed protection is considered to include (1) the trees and tall brush, (2) the herbs and shrubs growing thereunder or in openings in the forest or brush fields, (3) the litter of fallen leaves, branches, downed trees, and other vegetative material on the forest floor, and (4) the rich humus of partly decayed vegetable matter on the surface and in the top layer of the soil. The Act of 1897 which

Recognition
of watershed
protection
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first provided for administration of the original "forest reserve" named as a major purpose "securing favorable conditions of water flows". Certain of the National forests of the West, among them the Tonto in Arizona and the Angeles in California, have been created in whole or in large part principally for the protection of irrigation projects on municipal water supplies. The Weeks Law of 1911 provided for Federal cooperation with the state "for the protection of the watersheds of navigable streams" and for Federal "acquisition of lands for the purpose of conserving the

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navigability of navigable rivers." The Clarke-McNary Law of 1924 continued the cooperation "with a view to the protection of forest and water resources" and directed that in further purchases "due consideration" be given both to watersheds of navigable streams and those "from which ^{water} is secured for domestic use or irrigation." Note: This is from page 305.

Effect of forest on run-off

The more important ways in which forest cover brings about the beneficial effect on run-off are (1) interception of precipitation, (2) retardation of snow melt, (3) reduction of evaporation from the soil, (4) consumption of water by forest vegetation, (5) influence of forest litter.

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Because forests that conserve snow and reduce evaporation of soil and moisture must at the same time interrupt precipitation and transpire water drawn from the soil, its final effect on run-off can only be determined by the balance between these opposing influences. American research to date backed by a large body of observational evidence from all parts of the United States justifies the strong belief that the forests of the country practically always benefit stream flow.

A possible exception is the canyon bottom vegetation of the dry regions. Even this may prove to have a net favorable effect in the checking of erosion. There can be no doubt at all that the net effect of forest litter, although it intercepts some precipitation and returns it into the air by evaporation, it is extremely beneficial since it reduces surface run-off and increases the water storage capacity of the soil by increasing percolation at the same time that it shelters the soil moisture from evaporation.

Effect of forest on erosion

Erosion is taking place on all land areas. In humid regions completely clothed with vegetation as in a dense forest, natural processes are forming soil as rapidly as it is eroded and actual net loss, if any, is imperceptible. Where the forest and other vegetative cover is definitely scant as under semi-arid conditions, there is still enough vegetation or debris to catch

navigation of navigable rivers." The Alaska-Native Law of 1924 contained
the corporation "with a view to the protection of forest and water resources"
and directed that in further purchases "the consideration" be given both
to the needs of navigable streams and those "lands which are needed for
domestic use or irrigation." Note: This is from page 302.

The more important ways in which forest cover brings about the benefit
effect on run-off are (1) interception of precipitation, (2) retention of
snow melt, (3) reduction of evaporation from the soil, (4) consumption of
water by forest vegetation, (5) influence of forest litter.

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from evaporation.

Erosion is taking place on all land areas. In humid regions completely
clothed with vegetation as in a dense forest, natural processes are forming
soil as rapidly as it is eroded and actual net loss, if any, is inconceivable;
where the forests are other vegetation cover is definitely scantier under
such conditions. There is still enough forest to prevent erosion in the

eroding soil and litter on slopes, retard run-off and cause deposition of much of the eroded material already in motion. Even a light vegetative covering if undisturbed is sufficient to hold normal erosion to a negligible quantity. Only where the soil is unstable and easily erodible, as in the badlands of the Dakotas or on the outcrops of the Mancos and similar shales, is normal erosion sufficiently rapid as to be perceptible.

Effect of Fire

Observations at Guthrie, Okla., Experiment Station

See Bennett

Effect of Fire

Observations on Fish Creek and Santa Anita, Creek, Calif., p. 317

Types of disturbance of forest cover are by (1) fire, (2) improper logging, (3) overgrazing, (4) smelters, (5) clearing for agriculture.

Destruction of vegetation by smelter fumes at Ducktown, Tenn., Kennett, Calif., Anaconda and Butte, Mont., afford excellent examples of effect of destruction of forest cover on increasing erosion, pp. 325-326.

In the Northeast region it is particularly significant that many municipalities own watershed forests. In every State, communities have acquired part of the land from which they obtain water, and where these lands have required reforestation they have been planted. Some 350 communities in New York now possess municipal forests. New York City has the largest area on its Ashokan Reservoir drainage. Glens Falls has planted more than 2 million trees on the denuded land acquired as a city watershed. Cities and towns in Massachusetts own over 50,000 acres of watershed forests. Forty towns in Vermont possess municipal forests, largely for watershed protection. Newark, N. J., has a watershed forest of 35,000 acres. Private water companies own considerable acreage of forest land. Forests on municipal watersheds not only serve the local public by yielding good water, but they have returned revenues from the sale of forest products. (P. 339)

effect of fire - 2
A

Types of disturbance - 2
A

Smelter action - 2
F

Municipal watershed protection - 4

"Measurements were made by the Appalachian Forest Experiment Station of the dry weight of suspended matter found in streams of western North Carolina following heavy rains in August, 1928. These showed that as the percentage of cultivated area in the drainage increased, a progressive increase occurred in the amount of silt carried by the stream. This ranged from 4,370 parts per million on a watershed from 85 to 90 percent in cultivation to 11 parts on a watershed where only 5 or 10 percent of the area was cleared. The material obtained from the agricultural watersheds was fine sand, clay, and silt; from the forested watersheds, mostly organic matter." (P. 344)

In the Ohio Valley region a few progressive communities are protecting reservoir sites and watersheds by forest. For example, Akron, Ohio, has 5,000 acres in a municipal forest. Wellston, Ohio, has a 300-acre watershed above its storage reservoir. Denuded lands on this area have been planted. Other Ohio cities having municipal forests include Overland and Cincinnati. The Mahoning Valley Sanitary District, which supplies water to Niles, Youngstown, and Girard, possesses 4,500 acres.

Trout Creek, near Buena Vista, Colo., furnishes an outstanding example of the results of reduction of cover. Formerly this stream for 20 miles was clear and lined with willows and gave no evidence of erosion. Timber cutting in recent years has been followed by fire and overgrazing. The fertile bottomland soil has now been washed away, all the willows are gone, and the stream is imbedded in a deep, wide gully practically throughout its length.

"Fires in the chaparral, brush, and forest cover in these drainages are sometimes disastrous. A record fire that occurred during the fall of 1932, resulting from carelessness of a recreationist, consumed the forest cover on more than 200,000 acres in the southern part. The inevitable silting from erosion of fire-devastated slopes will seriously threaten the permanency of the Santa Barbara and Montecito reservoirs. The seriousness of this

"Measurements were made by the Appalachian Forest Experiment Station of the dry weight of suspended matter found in streams of western North Carolina following heavy rains in August, 1932. These showed that as the percentage of cultivated area in the drainage increased, a progressive increase occurred in the amount of silt carried by the stream. This ranged from 4,300 parts per million on a watershed from 85 to 90 percent in cultivation to 11 parts on a watershed where only 5 or 10 percent of the area was cleared. The material obtained from the agricultural watersheds was fine sand, clay, and silt; from the forested watersheds, mostly organic matter." (P. 30A)

In the Ohio Valley region a few progressive communities are protecting themselves with and established by forest. For example, Akron, Ohio, has 5,000 acres in a municipal forest. Wellston, Ohio, has a 300-acre watershed above its sewage treatment. Numerous lands on this area have been planted. Other Ohio cities having municipal forests include Cleveland and Cincinnati. The Sandusky Valley Sanitary District, which supplies water to Milan, Youngstown, and Girard, possesses 4,500 acres.

Trout Creek, near Burns Vista, Colo., furnishes an outstanding example of the results of reduction of cover. Formerly this stream for 20 miles was clear and lined with willows and gave no evidence of erosion. Timber cutting in recent years has been followed by fire and overgrazing. The fertile bottomland soil has now been washed away, all the willow stems gone, and the stream is incised in a deep, wide gully practically throughout its length.

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prospect is suggested by the silting of the Gibraltar Reservoir of the city of Santa Barbara that has followed fires.

A2
Gibraltar
Monteito

In 1923 and 1925 fires destroyed the brush and small-tree cover on 40,000 acres, or 30 percent, of the 133,000-acre drainage basin of this reservoir. By 1928, sediment washed into the reservoir by erosion from the burned area amounted to 6 percent of the reservoir's storage capacity, and large quantities of sand, gravel, and boulders were piled along the streams in position to be washed down in future years. In 1932, silt deposits occupied more than 14 percent of the reservoir's original capacity. Since construction of the reservoir cost \$57.50 per acre-foot of storage space, these erosion deposits have cost the city \$120,750 in the 10 years since completion of the project. The loss of investment in storage in the Gibraltar Reservoir, in 10 years, has been more than \$3 for every acre burned. Silting from a drainage densely covered by brush is comparatively slight. The entire forested area in this basin has been classed as having a major watershed-protection influence." (P. 424)

"Chief Engineer E. C. Eaton of the Los Angeles County Flood Control District is quoted in the bulletin Forestry in the State-Wide Water Plans as follows:

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effect
of
burns

Intense rains falling on a brush-covered watershed washed down only 400 cubic yards of debris per square mile, while the corresponding amount on adjacent burned-over areas rose to 12,000 cubic yards.

Even with the controlling influence of 300 check dams per square mile on the burned area, the detrital material still amounted to 7,000 cubic yards. It is further important to note that the brush cover not only proved to be a strong check on the debris movement, but that it also effectually functioned in reducing the surface run-off. With 1.36 inches of rain per hour the burned-over

project is suggested by the action of the...
city of Santa Barbara that has followed...

In 1932 and 1933 the... destroyed the brush and...
40,000 acres, or 30 percent, of the 133,000-acre...
reservoir. By 1935, sediment washed into the reservoir by erosion from
the burned area amounted to a percent of the reservoir's storage capacity,
and large quantities of sand, gravel, and boulders were piled along the
stream in position to be washed down in future years. In 1935, this deposit
occupied more than 14 percent of the reservoir's original capacity. Since
construction of the reservoir in 1931, 50 per cent-foot of stream silt
these erosion deposits have cost the city \$120,750 in the 10 years since completion
of the project. The loss of investment in storage in the Santa Barbara Reservoir,
in 10 years, has been more than \$5 for every acre burned. Settling from a
fireplace densely covered by brush is comparatively slight. The entire forested
area in this basin has been classed as having a major watershed-protection
influence." (P. 124)

"Chief Engineer E. C. Eaton of the Los Angeles County Flood Control
District is quoted in the Bulletin Forestry in the Santa-Barbara River Basin
as follows:

Intense rains falling on a brush-covered watershed washed
down only 400 cubic yards of debris per square mile, while the
corresponding amount on adjacent burned-over areas rose to
12,000 cubic yards.

Even with the controlling influence of 100 check dams per
square mile on the burned area, the debris was still
amounted to 7,000 cubic yards. It is further important to note
that the brush cover not only proved to be a strong check on the

Handwritten notes on the right margin, including a signature and the word "over".

area gave 1.01 inches in surface run-off while the area covered with brush produced only 0.42 inches. It follows that on the burned-off area only 0.35 inches of water were available for percolation * * * in contrast to 0.94 inches of water on the unburned area.

Such erosion debris rapidly impairs the permanency of flood-control and other reservoirs. Eaton, in discussing the Los Angeles flood-control district in the bulletin South Coastal Basin, points out that mountain fault lines limit the number of available reservoir sites and that construction on these sites would be costly." (P. 427)

Note effects of change in watershed conditions on floods and erosional debris in Utah, pp. 446-448. Look up article by Reed Bailey in Journal of Geology.

Effect of overgrazing

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9

"Soil Conservation" by H. H. Bennett

2
C Use table 7, p. 129, showing soil and water losses under cultivation and protective cover or revise this table if possible to include later data.

Losses of soil from areas devoted to clean-tilled crops were 62,955 times as great as on the same soils covered with dense vegetation. Water losses as immediate run-off ranged from 2.5 to 355 times as great. These data also show wide differences in relative erodibility of these different types of land. These differences result from differences in soil, slope, and a mountain intensity of rainfall as well as the type of crops used.

Notes on sizes of plots from which data in table 7 were taken.

	<u>Plot</u>
Bethany, Mo.	6 x 72.6 feet
Clarinda, Iowa	6 x 72.6 feet
LaCrosse, Wis.	6 x 72.6 feet
Hayes, Kans.	Do
Guthrie, Okla.	Do
Statesville, N. C.	Do
Zanesville, Ohio	Do
Temple, Tex.	Do
Pullman, Wash.	Do

Effects of degree of slope, length of slope, rainfall intensity, seasons, crop of rotation, cropping practices and direction/cultivation, organic matter, grass and forests, degree of erosion, and biological form on the rate of erosion are discussed pp. 149-168.

Effect of degree of slope, shown in table 8, p. 150.

Effect of length of slope, shown in table 9, p. 152.

Effect of rainfall intensity, shown in tabulation at bottom of p. 153.

Effect of season, shown in table 10, p. 155.

3 ~~Effect of crop rotation, shown in table 11, p. 157~~

3 ~~Effect of cropping practices and direction of cultivation, shown in table 12, p. 161.~~

Use made of p. 125, showing soil and water losses under various conditions and protective cover or which this table is possible to include later data. Losses of soil from areas devoted to clean-fallen crops were 63,935 times as great as in the same soils covered with dense vegetation. Losses as immediate run-off ranged from 2.5 to 355 times as great. These data also show wide differences in relative erodibility of these different types of land. These differences result from differences in soil, slope, and a somewhat intensity of rainfall as well as the type of crops used.

Notes on state of place from which data in table 7 were taken.

6 x 72.6 feet	Germany, Mo.
6 x 72.6 feet	Clinton, Iowa
6 x 72.6 feet	LaCrosse, Wis.
Do	Hayes, Kans.
Do	Clinton, Okla.
Do	St. Louis, Mo.
Do	St. Louis, Mo.
Do	St. Louis, Mo.
Do	St. Louis, Mo.
Do	St. Louis, Mo.
Do	St. Louis, Mo.

Effects of degree of slope, length of slope, rainfall intensity, season, crop rotation, cropping practices and other factors, organic matter, grass and forests, degree of erosion, and biological form on the rate of erosion are discussed pp. 125-126.

Effect of degree of slope, shown in table 8, p. 120.
Effect of length of slope, shown in table 9, p. 122.
Effect of rainfall intensity, shown in table 10, p. 123.
Effect of season, shown in table 11, p. 124.
Effect of crop rotation, shown in table 12, p. 125.

3 Effect of organic matter, shown in table 13, p. 162.

A 2 Soil and water losses from grass and forest areas shown in table 14, p. 163. This table also shows effects of burning of woods, and woods vs. grasslands.

2 Effect of past erosion on rates of soil loss shown in table 15, p. 165.

3 Effect of mulching shown in table 16, p. 166.

2 No specific data on effect of biological forms on soil and water conservation.

3 ~~Effects of crop rotation shown in tabulation, p. 343, and tabulation, p. 344.~~

3 ~~Effect of strip cropping shown in tables 31 and 32, p. 349, and table 33, p. 350.~~

3 ~~Effect of terracing in graph 33, p. 451, and graph 34, p. 452.~~

Soil conservation practices described by Bennett are as follows:

~~Crop rotation, pp. 339-346. Strip cropping, pp. 346-363. Vegetative control of gullies, pp. 363-368. Vegetative waterways, pp. 368-370. Seasonal cover crops, pp. 370-375. Green manuring, pp. 375-376. Use of crop residues, pp. 376-377.~~

~~Vegetation including grasses for pastures, leguminous pasture plants, meadow grasses, legumes for meadows a permanent cover, under-cover crops, shrubs, vines, succulents, and other plants, pp. 378-417. Also weeds, 417-418.~~

3 ~~Forestry, pp. 421-433. Field contouring, pp. 435-436. Pasture contouring, pp. 436-438. Range contouring, pp. 438-439. Flood-control contouring, pp.~~

~~439-441. Terracing, pp. 443-476. Run-off disposal, channelways and outlets,~~

~~pp. 477-495. Subsoiling and other sub-surface tilling, pp. 496-505. Gully~~

~~control, pp. 506-534. Highway erosion control, pp. 535-543. ^{Dams} ~~Towns, pp. 544-548.~~~~

~~Stream-bank erosion control, pp. 549-557. Water spreading, pp. 558-567. Wildlife planting, pp. 568-595.~~

Effect of organic matter, shown in table 13, p. 165.

Soil and water losses from grass and forest areas shown in table 14.

1. 163. This table also shows effects of burning of woods, and woods vs.

transpiration.

Effect of past erosion on rates of soil loss shown in table 15, p. 165.

Effect of rainfall shown in table 16, p. 166.

No specific data on effect of biological factors on soil and water con-

servation.

Effects of crop rotation systems, table 17, p. 167, and table 18.

p. 168.

Effect of strip-cropping shown in tables 19 and 20, p. 169, and table

21, p. 170.

Effect of terracing in table 22, p. 171, and graph 23, p. 172.

Soil conservation practices described by Bennett are as follows:

Crop rotation, pp. 173-180. Strip-cropping, pp. 181-186. Vegetative control of

erosion, pp. 187-194. Vegetative waterways, pp. 195-200. Seasonal cover crops,

pp. 201-206. Green manures, pp. 207-212. Use of crop residues, pp. 213-217.

Vegetation including grasses for pastures, leguminous pasture plants, meadow

grasses, forage for hedges, permanent cover, under-cover crops, shrubs,

vines, succulents, and other plants, pp. 218-227. Windbreaks, pp. 228-233.

Forestry, pp. 234-243. Field contouring, pp. 244-250. Pasture contouring,

pp. 251-256. Ridge contouring, pp. 257-263. Flood-control contouring, pp.

264-271. Terracing, pp. 272-280. Run-off disposal, channels and cutoffs,

pp. 281-287. Subsoiling and other sub-surface tillage, pp. 288-295. Mulch-

control, pp. 296-303. Highway erosion control, pp. 304-311. Dams, pp. 312-318.

Stream-bank erosion control, pp. 319-327. Water spreading, pp. 328-334. Willows

planting, pp. 335-337.

Besley (17) has quoted Mr. Charles G. Adsit, vice president and executive engineer of the Georgia Railway & Power Co., in 1922, as follows:

At our Morgan Falls Plant on the Chattahoochee River, which is below large cultivated areas, the reservoir in 1904 covered 750 acres. After ten years' service, there was no reservoir capacity worth mentioning left, it having all silted shut, leaving only a channel through the center of the reservoir for the river flow. On the other hand, our Mathis Reservoir, above which is only forested area, after ten years' service, shows little or no sign of silt whatsoever.

~~He also notes that Mr. Edgar P. Kable, general manager of the York Water Company, York, Pa., made this statement in 1927,~~ as follows:

Our observations of the effect of forest planting on our water supply in dry times has been that it has increased the dry weather run-off very materially.

We have a 700 acre tract planted with 680,000 evergreen trees and although we have no gauge at present, nor did we have prior to the building of the dam, yet this fact is noticeable.

The quality of the water in the stream has also materially improved as there is very little erosion from the banks, and, as an example, when there was a great downpour of rain * * *, the water in this dam remained clear, whereas some of the neighboring streams became very turbid.

For any one to deny the beneficial effects of a forest cover in preventing erosion is to refuse to accept the preponderance of evidence from competent sources for a hundred years or more.

Municipal
afforestation
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has been...
...in 1932, as
follows:

At our former site...
which is below...
750 acres. After...
capacity...
only a...
flow. On the...
only...
sign of...

...
Our observations...
water supply...
weather...

We have a...
and although...
to the...
the quality...
improved...
an...
water to...
streams...

For any...
in...
evidence...

Handwritten note:
...
...

71-11

Ritchie (91), in discussing the relation of forests to water conservation in Australia, made a plea for preservation of large trees, (that is, virgin timber stands) because of their effects (1) in moderating evaporation losses through shade production and wind breaking, (2) increasing percolation through extensive root development, thus assisting in maintaining perennial streams, and (3) reducing the size and cost of artificial storage reservoirs by retarding soil erosion and equalizing stream flows.

Afforestation

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5

Ritchie counters the argument for obtaining revenue from timber cutting in municipal reservoir drainage areas by pointing out that the 160 square miles of forested drainage area above three Melbourne city reservoirs would be sufficient to serve an urban area of 1,400,000 persons. Taking the population density of a typical area as 15,600 persons per square mile, the proportion of forested area to densely populated area is about 1-3/4 acres of forest land to 1 acre of urban area. He argues that it would be the best of economics to reserve 2 to 3 acres of forest area in virgin state for every acre of densely populated urban area in order to assure a stable water supply.

Ritchie argues, furthermore, that every influence should be exerted to bring about cessation of the practice of leasing Crown lands in the mountainous forest areas for grazing purposes. It was his conviction that this was a foolish and short-sighted policy, and had been responsible for more damage to the forested watersheds, than any other form of fire occurrence.

Deforestation

B 2

As an illustration of the beneficial effects of forests in relation to water supply, Ritchie recounts an experience told by the chief engineer of the Goldfields Water Supply, West Australia. This agency had experimented on part of the drainage area of Mundaring Reservoir, which

Nichols (21), in discussing the relation of forests to water

conservation in Australia, made a case for preservation of large tracts of virgin timber areas (2) because of their value (1) in maintaining watershed losses through soil preservation and wind breaking, (2) in creating opportunities through extensive root development, thus resulting in maintaining perennial stream flow, and (3) reducing the size and cost of artificial storage reservoirs by retaining soil erosion and equalizing stream flows.

Nichols contrasts the argument for obtaining revenue from timber cutting in municipal reservoir drainage areas by pointing out that the 100 square miles of forested drainage area above these reservoirs city reservoirs would be sufficient to serve an urban area of 1,000,000 persons. Taking the population density of a typical area as 15,000 persons per square mile, the proportion of forested area to densely populated area is about 1-3/4 acres of forest land to 1 acre of urban area. He argues that it would be the best of economies to reserve 3 to 5 acres of forest area in urban area for every acre of densely populated urban area in order to assure a stable water supply.

Nichols argues, furthermore, that every influence should be exerted to bring about cessation of the practice of logging from lands in the mountainous forest areas for stream purposes. It was his conviction that this was a foolhardy and short-sighted policy, and has been responsible for some damage to the forest resources, than any other form of the occurrence.

As an illustration of the beneficial effects of forests in relation to water supply, Nichols recounts an experience told by the chief engineer of the California Water Supply, and illustrates the many values

Besley notes that forest cover furnishes cheap protection, reduces evaporation from the land surface, ^{and} provides a source of revenue in the timber. He points out that planting for the protection of watersheds is most needed on the upper, steeper slopes where soil erosion is in progress to the greatest extent. He advocates planting along the shoreline of the reservoir not only for the purpose of holding the banks but also to improve the appearance of the water line. Where the banks are badly eroded by wave action, however, he suggests a bedding of green willow poles or small logs in the bank perpendicular to the slope with the lower ends of the logs in the water. The willow logs will send suckers out above the water and these in time will take root in the sides of the banks forming a network to hold the soil in place.

An anonymous article ⁽⁹⁸⁾ in 1930 notes that the ~~City~~ Water Works Department of Akron, Ohio, had developed a transplant nursery in which more than 200,000 seedling trees ^{were} are growing to a size that will enable them to compete with heavy sod for watershed protection. In Barberton, Ohio, the ~~City~~ Water Works Department began planting on a large scale in 1930. It is planned, along with the reforesting of idle land, to develop a wide shelter belt of pine or spruce all around the large city reservoir. Such a shelter belt would prevent much debris from being carried into the water, in addition to acting as a soil binder.

In a round-table discussion on the problems of silting in water-works reservoirs, ⁽⁹⁹⁾ S. T. Anderson, superintendent of the water department at Springfield, Ill., reported that three methods of silting control had been tried. (1) Protecting shoreline against wave action by riprapping, (2) seeding to grass about 5,000 acres of marginal land in the drainage area that had been under cultivation, (3) planting other marginal land with trees preferably of the evergreen type. These methods were all applied on land owned by the city. In addition, property owners in the

Shore 3
Protection

Municipal
afforestation

Planted
350,000 trees
along
shoreline
1928-38.
Scotch red &
white pine.

Municipal
afforestation

drainage area were encouraged to protect their soil from erosion.

Municipal
afforestation No 41
completed

Mr. W. C. Wills, chief engineer at Wilmington, Del., reported ^{recently} reforestation ^{billions} of the entire marginal strip around the 2.2 million gallon Edgar Hoops ⁸ storage Reservoir. Trees were planted on 6-foot centers ^{in 1933 and 1934} ~~3 or 4 years previously~~. The effect ^{the planting could not} of silting cannot yet be judged, ^{as early as 19}

Watershed
control

Bryan, in discussing the paper by Taylor (9, p.), points out that vegetation is most effective in decreasing erosion ^{on} of hill slopes, on alluvial fans and at the heads of gullies, and that after the water is concentrated in the valley floor a good growth of grass tends to spread the water and keep it spread, which means that the sediment is brought down more slowly. A decrease in vegetation, particularly grass, whether brought about by overgrazing or change in climate to greater aridity causes the formation of a channel. Thus, even though general erosion may decrease ^{with a} ~~by a~~ smaller amount of run-off, a special and concentrated stream erosion may ensue and the production of sediment may be greater. Successful control, Bryan says, depends upon (1) reasonable restriction of grazing, (2) introduction of drought resistant plants that are not palatable to stock, ^{such as} salt cedar, ~~etc.~~, and (3) construction of retarding and retaining works.

Policy

Saville (18, p.) states that it is probable that the power companies may later find it economical to adopt erosion-control methods to prevent or lessen the amount of silt and sand now being carried by the streams into the Deep River reservoirs. He believes that such a policy would not prove unduly expensive and that it should be considered by any company proposing to carry out a ~~drainage area~~ scheme of ^{complete reservoir} unit development of ~~the~~ ^{a drainage basin} river.

drainage area were estimated to protect them from erosion.

Mr. W. O. Miller, Chief Engineer at Wilmington, Del., reported that

the necessity of the entire marsh area around the S. S. station

along the river would be destroyed. These were planned on a long term

basis. The effect of the entire marsh area on the river

is discussed in the report of Taylor (1911). It is noted that

vegetation is most effective in retarding erosion of all slopes on

alluvial lands and at the heads of gullies, and that where the water is

concentrated in the valley floor a good growth of grass tends to retard

the water and thus to arrest which means that the sediment is brought down

more slowly. A decrease in vegetation, particularly grass, which brought

about by overgrazing or change in climate to render aridly causes the

formation of a channel. Thus, even though general erosion may decrease

by a smaller amount on the alluvial and concentrated side an erosion

may ensue and the production of sediment may be greater. Successful

control, Taylor says, depends upon (1) immediate restriction of grazing;

(2) introduction of drought resistant plants that are not palatable to

stock, and (3) construction of retaining and retaining

works.

Miller (1911) states that it is probable that the power companies

may later find it necessary to adopt erosion-control methods to prevent

or lessen the amount of silt and sand now being carried by the stream.

into the deep river reservoirs. He believes that such a policy would not

prove unduly expensive and that it would be considered by any company

proposing to carry out a scheme of water development of the

river.

Rodwell (32) advocates public control of drainage areas of reservoirs ^{in England} ~~supplying water to the public~~ ^{for domestic use} because of the effect of these drainage areas in bringing down large amounts of sediment as well as in increasing the cost of filtering out impurities. He advocates the wide extension of afforestation because of its beneficial effects in reducing turbidity and improving the standard of purity in the water. Figure ~~after Rodwell~~ shows the results of ~~an attempt to compare~~ ^{Rodwells} the turbidity of water flowing from contiguous areas ^{isn't} exactly similar in character and elevation but separately drained, one of which has been afforested, another partly forested, and a third left bare. Although records of the rate of run-off and the amount of heavier debris carried are not available the comparative turbidities are suggestive of beneficial the/effects of afforestation. In England, Rodwell states, the proved reduction of turbidity and enhanced purity of water drawn from afforested areas have in themselves been sufficient incentive for water authorities to embark on schemes of afforestation.

Orth (24) maintains that treatment of the catchment area should consist of the construction of many small check dams of the type used in mountain torrent obstructions, plus reforestation. He argues that complete control of the formation of debris is not only impossible but undesirable because the river would begin to degrade itself and pick up additional material from its bed and banks with unsatisfactory results. ^{Orth does not recognize, however,} ~~It should be noted that~~ such degradation would occur only if the coarse material were cut off and would not result from the reduction of the load of fine material which constitutes 90 percent or more of the total sediment ^{transported by many streams in the} ~~deposited in many reservoirs.~~ United States.

Fig.
afforestation

2C

5

check dam control

3

Stream
bank
erosion 4

The effects of the attempts to control stream-bank erosion in the drainage area above Zuni Reservoir as a measure of silting control have already been noted (pp.).

Check
dam
control

3
11

Eaton (92) cites the cost of erosion control by check dams in the 2.15-square mile drainage area of Horse Canyon, a tributary of the San Gabriel River, Calif. In the summer of 1932 this drainage area was completely covered by 23 rock and wire check dams and 137 loose rock dams, representing a total of 1 dam for each 6.25 acres. The cost per square mile of this work was \$10,445 and the cost per cubic yard of debris storage was estimated at \$0.51. Lippincott, in discussing Eaton's paper, notes that flood-control work on Lambac Creek near Brienze, Switzerland, consisting of substantial check dams and channel paving throughout the drainage area of 1.66 square miles, resulted in expenditure between 1898-1913 of \$130,000 per square mile.

Vegeta-
tion after
burns 3

Kotok and Kraebel, discussing a paper by Eaton (92, pp.), note that the effect of reseeding burned watersheds in Southern California with mustard, an emergency measure of vegetative control, cost \$1.25 per acre when sown by hand and \$0.90 per acre when sown from an airplane.

Road
erosion

G 2

Frank (93) states that studies of reservoir sedimentation in the San Francisco peninsular region of hilly terrain shows that the major cause of storage loss is serious erosion resulting from sliding and slumping on State and county highway construction. Road cuts vary from 3 to nearly 70 feet. One of the major cuts, 50 feet high and very steep, produced a slide of over 200 cubic yards. It is almost impossible to reduce the gradient of this slope in view of its length and steepness and the large amount of material involved, and it is Frank's opinion that this cut will continue to give rise to slides.

Stream
bank
erosion 3

Hemphill (65) would rely for stream-bank erosion control mainly on flood-control reservoirs. He feels these could be supplemented, however, by barriers of brush in smaller channels and lines of living brush across flood plains and larger channels, which would cause deposition of part of

The estimate of the amount of material to be removed from the
channel above the dam is a matter of about 100,000 cubic feet
of earth and rock.

Station (92) shows the cost of erosion control by check dam in the S. 15-
square mile drainage area of Horse Canyon, a tributary of the San Gabriel
River, Calif. In the summer of 1932 this drainage area was completely
covered by 25 rock and wire check dams and 150 loose rock dams, representing
a total of 1 ton for each 0.25 acre. The cost per square mile of this
work was \$10,000 and the cost per cubic yard of debris storage was estimated
at \$0.50. In discussing Station's paper, notes that flood-control
work on larger rivers near Denver, Switzerland, consisting of substantial
check dams and channel paving throughout the drainage area of 1.66 square
miles, resulted in a reduction between 1928-1932 of \$100,000 per square mile.
Kotok and Kiesel, discussing a paper by Eaton (93, p. 1), note
that the effect of retarding burned watersheds in Southern California with
masonry, an emergency measure of vegetative control, cost \$1.25 per acre
when done by hand and \$0.50 per acre when done from an airplane.

Frank (94) states that studies of reservoir sedimentation in the
San Francisco watershed region of Italy indicate that the major cause
of erosion loss is surface erosion resulting from sliding and slumping on steep
and highly dissected country. Road cuts vary from 3 to nearly 50 feet.
One of the major cuts, 50 feet high and very steep, produced a slide of
over 200 cubic yards. It is almost impossible to reduce the gradient of
this slope in view of the high steepness and the large amount of
material involved, and it is Frank's opinion that this cut will continue
to give rise to slides.

Waghill (95) would rely for stream-bank erosion control mainly on
flood-control measures. He feels that there could be no dammed, however,
by barriers of debris in smaller channels and that if debris were given

the sediment load.

Water spreading 3
Taylor (9), Hemphill (65), and Faris (13) have all advocated various types of water spreading on waste flood plain and alluvial lands as a means of causing sediment deposition within the drainage basin, thereby preventing its reaching the reservoir.

Forest burns
B 2
Bates and Henry (93) have reported the following results from the Wagon Wheel Gap, Colo., experimental watersheds of approximately 200 acres each. During the period from 1910-1919, watershed A delivered 691.5 pounds of sediment dry weight annually and watershed B delivered 568.5 pounds. In 1919 and 1920 watershed B was denuded by burning. For the second period, 1920-1926, watershed A delivered an average of 477 pounds and watershed B, 3,340.1 pounds. The ratio of B over A therefore increased from 0.822 to 7.002 or was about $8\frac{1}{2}$ times as high after denudation. The load of sediment carried before denudation by both streams was very small, this being due to the coarse textured, highly porous soil and regular melting of the snow.

Afforestation 5
Long (94), in advocating the afforestation of water catchment areas in England, concluded that forests tend to increase locally the water supply, improve conservation, and assist in insuring purity. To these benefits he adds two further considerations, first, that forestry employs more labor than a system of husbandry generally adopted on areas selected as gathering grounds and can thus help toward alleviating employment, and secondly, the increasing esthetic value of the area, when afforested generally appeals to the public and to the officials of the section which it serves.

Deforestation B 2
Wood (95) has noted the effect of deforestation upon run-off and erosion in Southeastern Australia. He cites silting in Burrinjuck Reservoir (see p.) as an example to show that action to control further deforestation should be taken immediately.

Taylor (2), Washburn (3), and White (4) have all reported various types of soil erosion in the Snake River and adjacent lands as a means of causing sediment deposition within the drainage basin, thereby preventing the use of the reservoir.

James M. Henry (5) has reported the following results from the Snake River, Idaho, experimental watershed of approximately 300 acres area. During the period from 1910-1919, watershed A delivered 691.2 pounds of sediment per acre per year and watershed B delivered 106.2 pounds. In 1919 watershed A delivered an average of 417 pounds and watershed B, 3,340.1 pounds. The ratio of B over A therefore increased from 0.422 to 7.002 or was about 6 times as high after denudation. The loss of sediment carried before denudation by both waters was very small, this being due to the coarse textured, highly porous soil and regular settling of the same.

Long (6), in advocating the afforestation of water catchment areas in England, concluded that forests tend to increase locally the water supply, improve conservation, and assist in insuring purity. To these benefits he adds two further considerations, first, that forestry employs more labor than a system of sheep or generally engaged on areas covered as gathering forests and can thus help toward afforestation, and secondly, the increasing economic value of the area, when returned generally appeals to the public and to the officials of the nation with its success.

Wood (7) has noted the effect of afforestation upon soil erosion in Pennsylvania. He observed that the effect of afforestation is to reduce the erosion as an example to show that action to control further deforestation should be taken immediately.